

Optimizing The Value of Your Unloaded Catalysts

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Today you will learn about...

- You will learn the best way to reuse your spent catalyst
- You will learn the way a spent catalyst is recycled
- You will find out the true value of the unloaded catalyst

Agenda

Spent catalyst management

Reuse of the spent catalyst

Recycling of the spent catalyst

Settlement operations

Spent Catalyst Management

Why unloading a catalyst?

Basics of deactivation

3 R principle

Reduce
Reuse
Recycle

Waste compliance in Europe

Basics of deactivation of catalyst

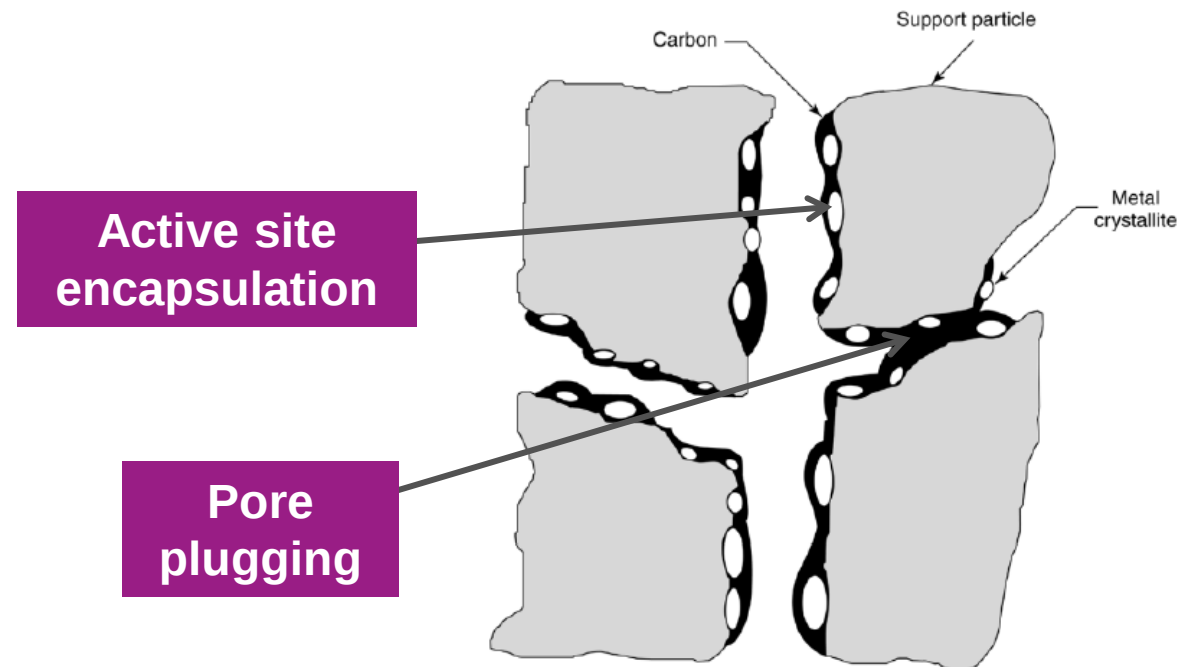
Catalysts life in refining or petrochemical applications:
minimum 6 months and usually 1 to 3 years

Main causes of catalyst deactivation

1 Coke deposition blocking active sites and catalyst porosity

2 Sintering of active phases

3 Contamination



Basics of deactivation of catalyst

Catalytic process	Catalyst	Coke deposit	Sintering of active phase	Contamination
Diesel Hydrodesulfurization	NiMo-CoMo / Al ₂ O ₃	+++	++	+
Resid hydrotreatment	NiMo-CoMo / Al ₂ O ₃	+++	+	+++
VGO Hydrocracking	NiMo-NiW / Silica alumina zeolite	+++	+	+
Naphtha Reforming	Pt Re Cl / Al ₂ O ₃	+++	++	+
Pygas, olefins, Selective hydrogenation	Pd – Ni / Al ₂ O ₃	++	+	++
Alkylation Aromatics/olefins	Zeolite + binder	+++	-	+

Sustainable alternatives for an unloaded catalyst?

3 R principle for sustainability

REDUCE

Reduce the production of fresh catalyst

REUSE

Reuse the catalyst after the regeneration

RECYCLE

If the quality is not met, recycle the catalyst for precious/base metal recovery



Waste compliance of the unloaded catalyst in Europe

- 1. Waste definition (EC/2008/98: Art. 3.1) means any substance or object which the holder discards or intends or is required to discard
- 2. Waste treatment = preparing spent catalyst for being reused or recycled
- 3. Catalysts considered as waste shall be transported according to regulations pertaining to the transport/transfer of wastes (EEC N°1013/2006)

EWC Definition

16 08 01 spent catalysts containing gold, silver, rhenium, rhodium, palladium, iridium or platinum (except 16 08 07)
16 08 02* spent catalysts containing dangerous transition metals (3) or dangerous transition metal compounds
16 08 03 spent catalysts containing transition metals or transition metal compounds not otherwise specified
16 08 04 Spent fluid catalytic cracking catalysts (except 16 08 07)
16 08 07* spent catalysts contaminated with dangerous substances

Reuse of the spent hydrotreating catalyst

**Regeneration of
catalyst**

Excel Rejuvenation

Catalyst cascading

**Reuse of 3rd party
main catalyst**

Regeneration of hydrotreating catalyst

Objectives

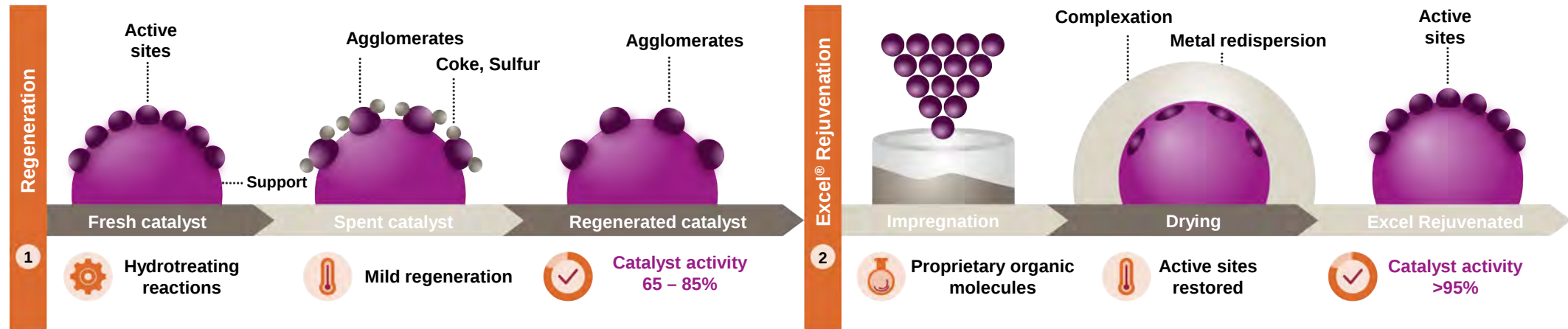
- Restoration of lost activity
- Maintenance of desired selectivity
- Maintenance of physical properties
- Minimization of disposal liabilities
- Minimization of down time

All these objectives can be achieved with ex-situ regeneration



Excel® Rejuvenation

Why Rejuvenate?



1st step: Regeneration

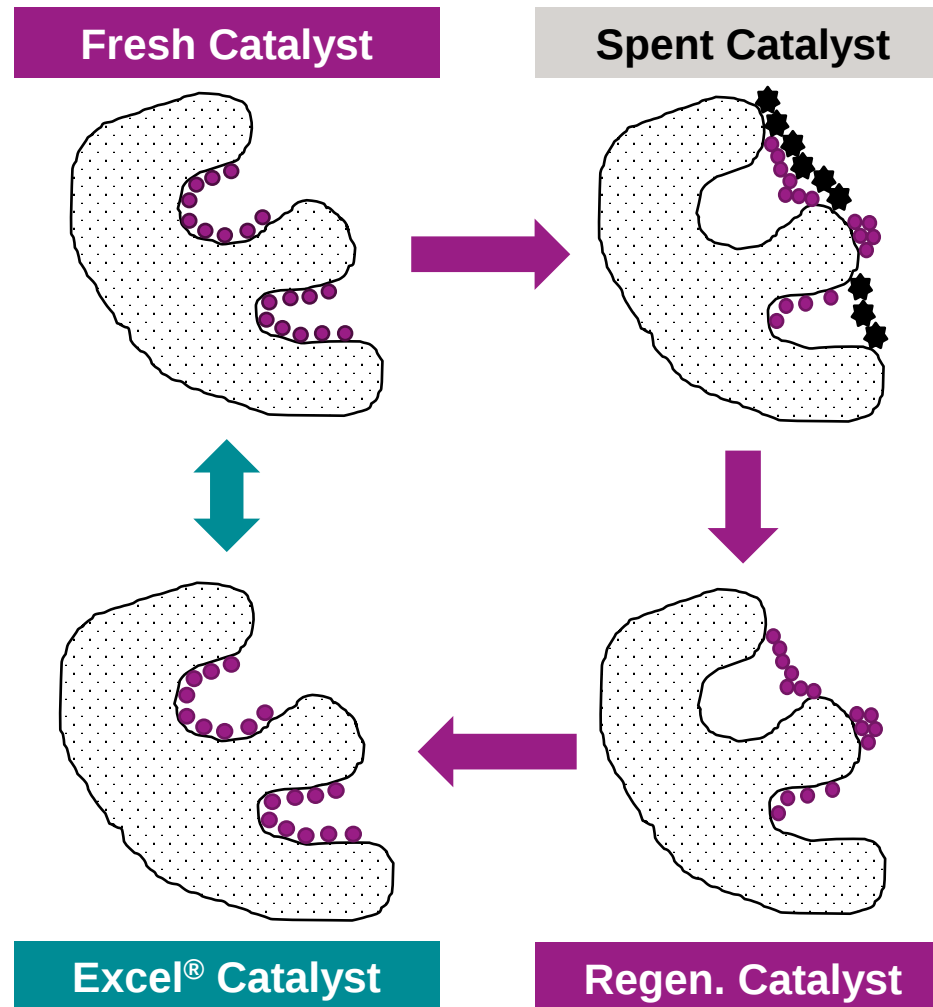
- Maximize sulfur and carbon removal while carefully controlling local temperatures
- Unique moving belt process to minimize catalyst breakage (attrition) and maximize yield

2nd step: Excel® Rejuvenation

- Patented technology
- Applicable to all type 1 and type 2 catalysts
- Activity restored to near fresh levels

Excel® Rejuvenation

Why rejuvenate?

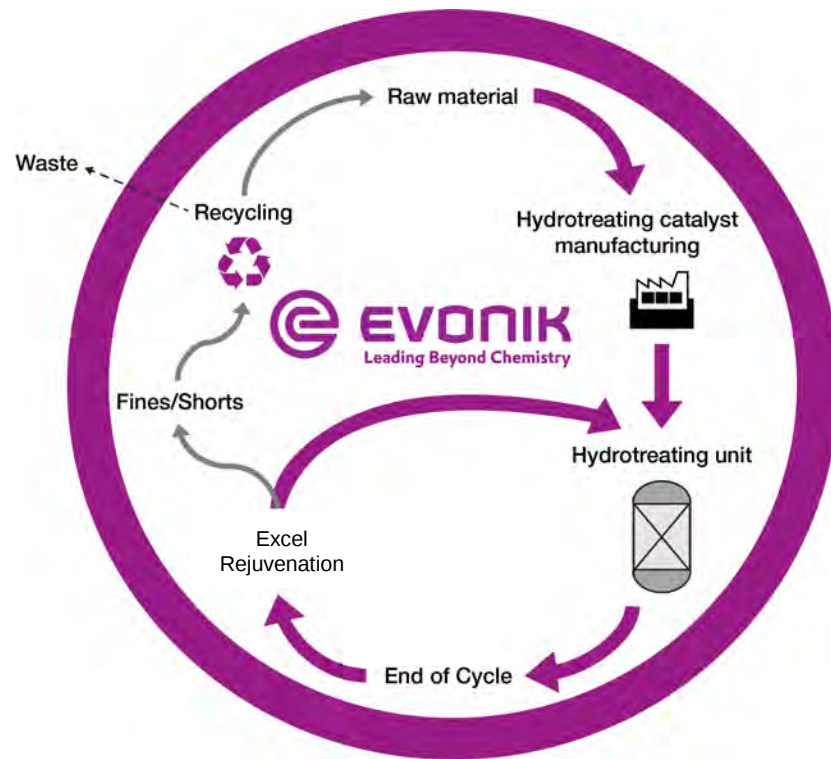


● Active metal sites

★ Coke

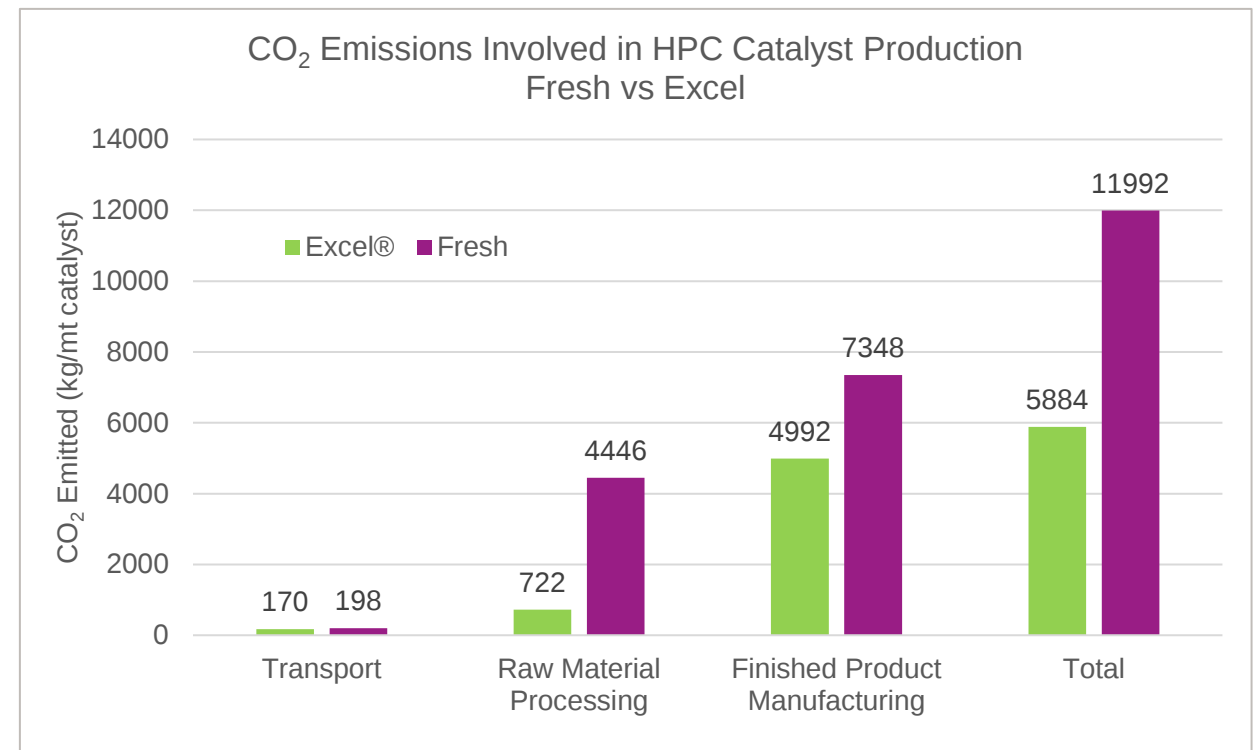
- Formation of **metal agglomerates** during cycle
- **Decreased activity**
- **Coke removal** during regeneration
- **Dispersion of metals** during Excel® treatment
- Return **activity near fresh**

Excel® Rejuvenation Sustainability



- For each ton of Excel catalyst used, refiners **avoid generating ~6 mt of CO₂** as compared to purchasing fresh catalyst for one-time use

- Use of a rejuvenated catalyst results in a **~65% reduction in CO₂ emissions**
- Regenerated or Excel rejuvenated catalysts actively contributes to the **Circular Economy**



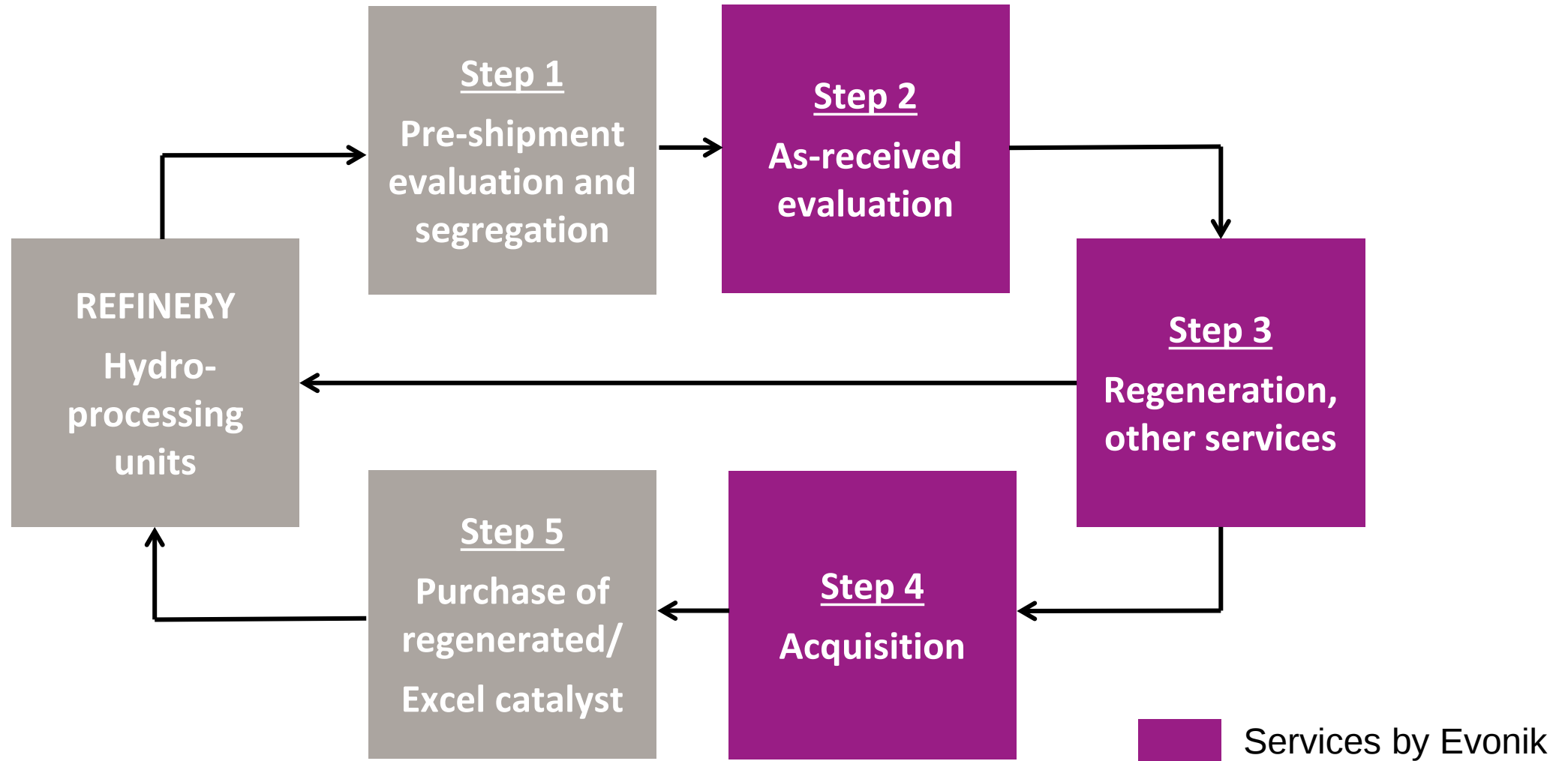
Excel® Rejuvenation Summary

Why Rejuvenate Hydrotreating Catalysts with Evonik's Excel® Technology?			
PERFORMANCE	 Restore activity to near fresh level	 Achieve similar stability vs fresh	 No loss in reactor performance
	 Lower refill cost	 Up to 50% of cost savings	 Example: 278m³ catalyst resulted in about 1.3 Mln € of cost savings
	 Maximize catalyst reuse & minimize catalyst waste	 Contribute to circular economy & carbon footprint reduction	 Reduce by about 65% Greenhouse Gas Emissions compared to fresh

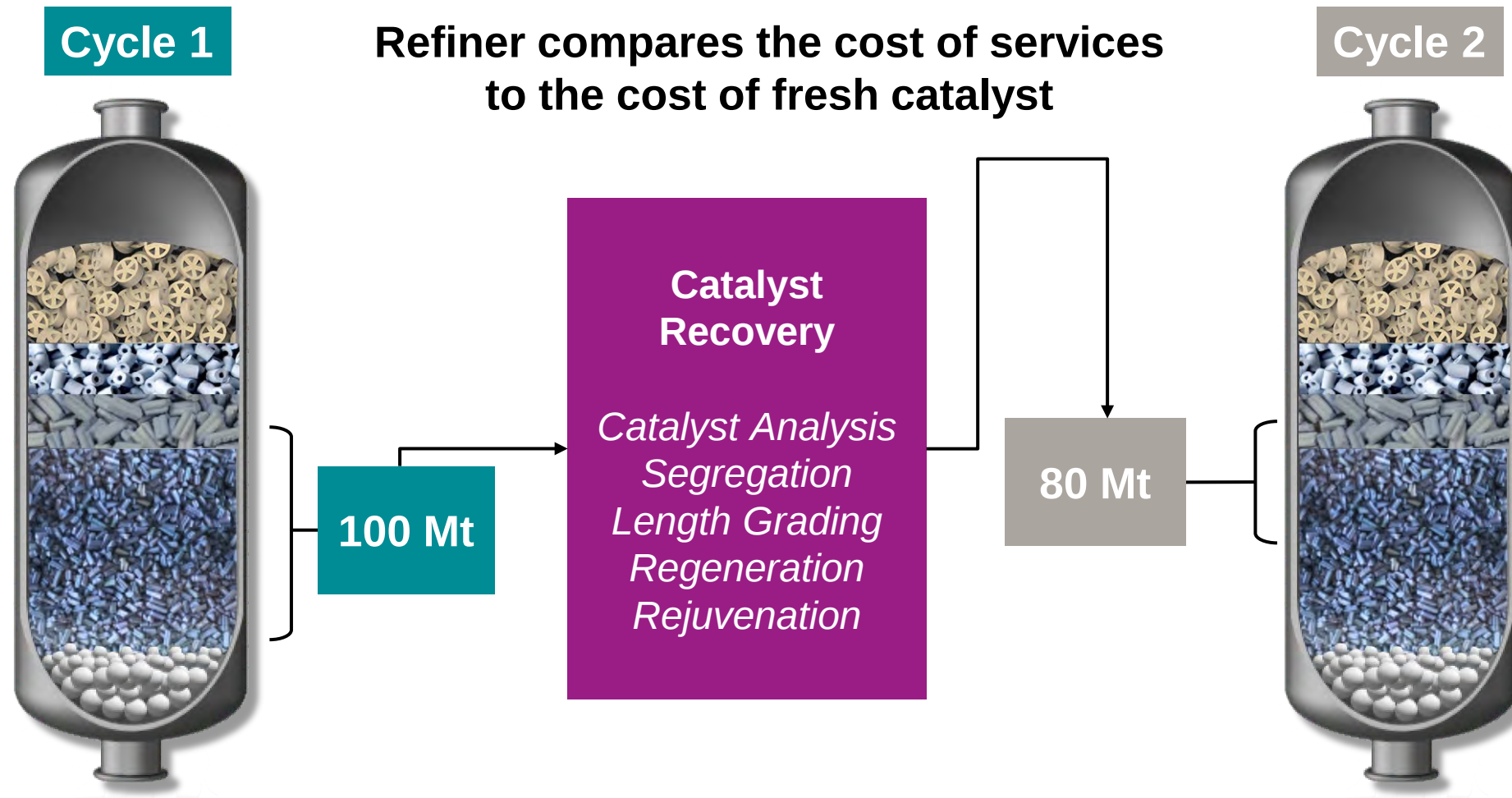


Catalyst cascading

Catalyst management



Catalyst Cascading Concept



Reuse of 3rd party main catalyst

Full Reactor Loading



Top Bed Grading

CatGuard® products:
20 – Hydrogenation control
Si21 – Silicon trap
As40 – Arsenic trap

Main Catalytic Bed

Regenerated
Excel® rejuvenated

Ceramic Bed Support

Durocel® 222

Evonik can design
a Full Reactor Load
(FRL) from the top
grading through the
main bed to meet
your specific
processing
objectives and
product quality
targets.

Recycling of the unloaded catalyst

Value perspective

Recycling process

**Settlement
operations**

Recycling of the spent catalyst

Molybdenum

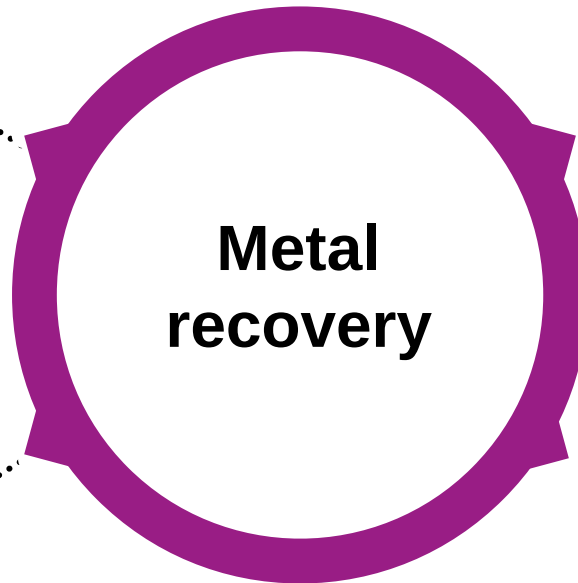
- NiMo
- CoMo
- NiMoV
- MoP
- MoBi
- MoCu

Precious metal

- Platinum – Pt
- Palladium – Pd
- Silver – Ag
- Gold – Au

Mo

Precious
metal



Nickel

- Ni rings / pellets
- Raney Nickel
- Nickel fat
- NiCu
- NiW

Ni

Others

Cobalt -Co

- CoMn

Vanadium- V

- V ash

Copper – Cu

- CuZn
- CuCr

Tungsten -W

- WNi
- WNiMo
- Wti

Iron/Chromium – Fe/Cr

Aluminium – Al

Value prespective

Positive value

Metal Value $\gt$ Treatment Cost

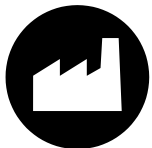
Negative value

Metal Value $\lt$ Treatment Cost

Metal recovery process

Reception
Handling, weighting and sifting

01



02

Recycling treatment

- Thermal treatment
- Melting
- Leaching

Sampling and analysis

03



04

Settlement



The products are mainly used as raw materials for the production of fresh catalyst, stainless steel, or special alloy industries.

Settlement operations of base metals

Market price

Platts Prices or Metal Bulletin prices

Offer set up

% of value of the weighted metal in the catalyst

**Deduction of the treatment fees and total
LOI**

Penalties on contaminated catalysts

CONCLUSION

Evonik can assist you with the management of your unloaded catalyst for reuse or recycling and give the best value of it.

Optimizing The Value of Your Unloaded Catalysts, Part 2

Precious Metal Settlements

Michael Ross
Director Custom Catalysts

Precious Metal Settlements

What you will learn

- Why do precious metal settlements (or not)?
- What are they?
- The basic mechanics of a settlement
- Some hints and best practices to ensure a quality and fair settlement

Precious Metal Settlements

What is it and Why

Precious metal settlements provide a method to determine and settle on the quantity of precious metal contained in a material, e.g. spent or fresh catalyst.

Precious metals are often provided by the customer for fresh catalyst manufacture and the settlement is a means to establish the contained quantity delivered.

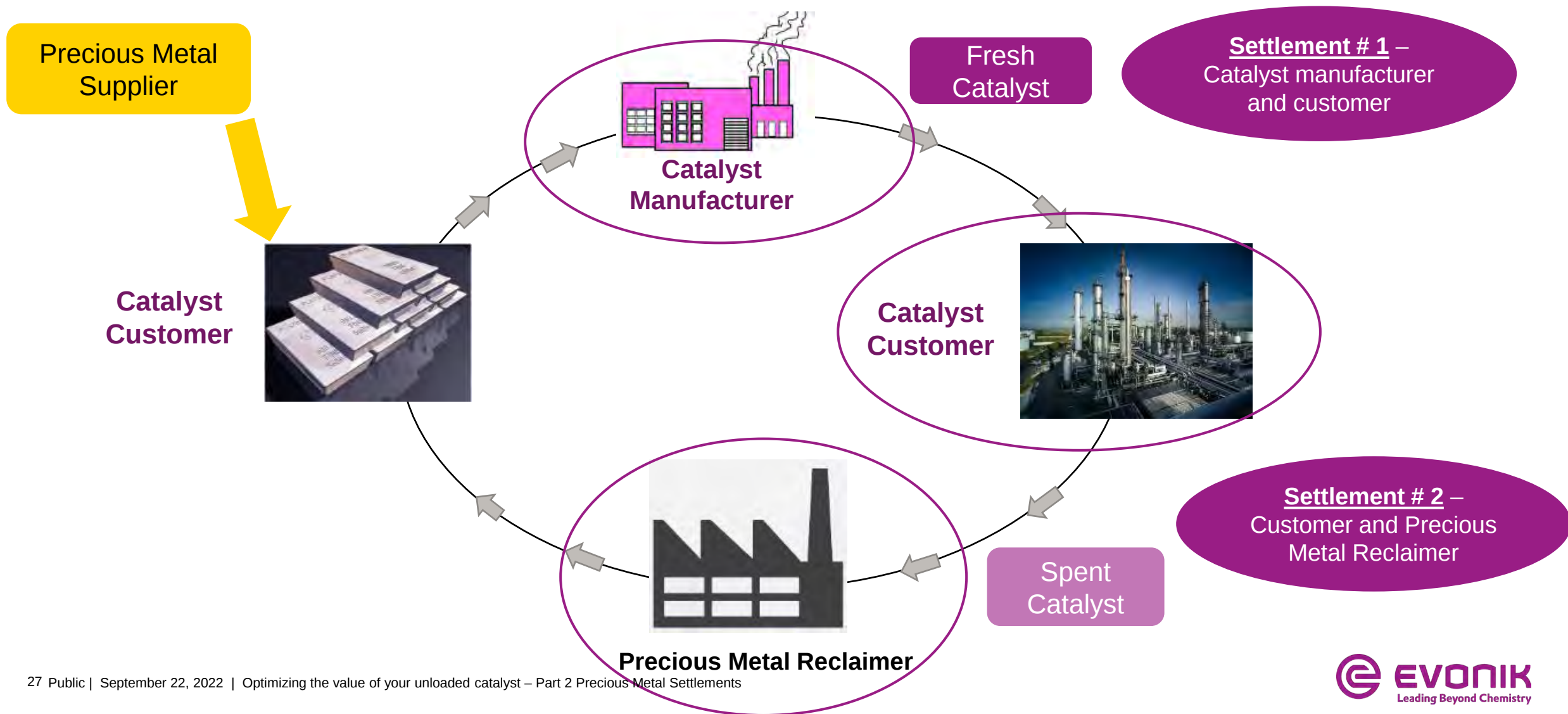
For spent catalyst, both parties want a fair and accurate method to establish precious metal content

Why we may not do them:

- Sometimes due to the nature of the catalyst, an accurate content is too difficult to establish
- Quantity of precious metal contained may not justify a settlement
- Negotiated commercial terms

Precious Metal Settlements

Precious metal cycle



Key Terms and Definitions

Party Assay – The precious metal assay from each party involved in the settlement procedure

Umpire – 3rd party assay lab mutually agreed between the parties

Relative Difference – the absolute difference between the two party assays divided by the average of the party assays

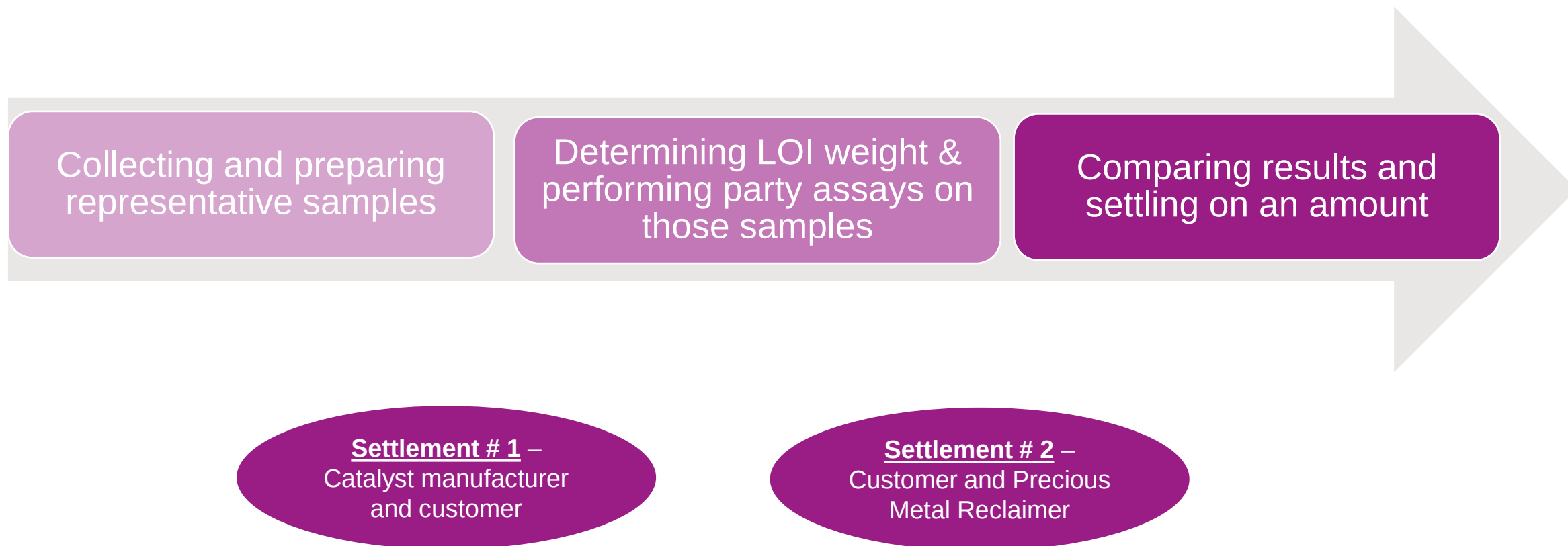
Splitting Limit – a mutually agreed maximum Relative Difference which would allow for the party assays to be averaged to establish the settled assay

LOI / LOD – Loss On Ignition and Loss On Drying

LOI / LOD Weight – the weight of the catalyst (fresh or spent) with moisture or volatiles removed

Representative – 3rd party company or individual hired to represent a company's interest, e.g. at a reclaim company or catalyst manufacturer

The Basic Mechanics of a Precious Metal Settlement



The Basic Mechanics of a Precious Metal Settlement

Collecting and preparing representative samples

Catalyst
Sampling

- ❑ Samples must be representative of the packaged catalyst or reclaimed/spent catalyst
- ❑ Small samples taken at a regular frequency or small split continuously taken
- ❑ Samples taken are protected from the environment, e.g. no loss or gain of moisture

Sample
Prep

- ❑ Typically, the small samples taken in production are riffled (mixed) in a lab to create a sample composite (usually represents a production lot)
- ❑ Care must be taken to ensure proper riffling without exposing to the environment where loss/gain of moisture can occur → use of a glove box is highly recommended
- ❑ Final lot composite is split into several sets of assay samples and LOI or LOD samples

The Basic Mechanics of a Precious Metal Settlement

Determining LOI weight & Performing party assays on those samples

LOI Weight

- ☐ Ensure LOI Weight sample is always protected from the environment, e.g. no gain or loss of moisture
- ☐ Establish clear procedure for handling and determining LOI to ensure a quality result
- ☐ Validate your method and if sending to 3rd party, provide clear and specific instructions

Assay

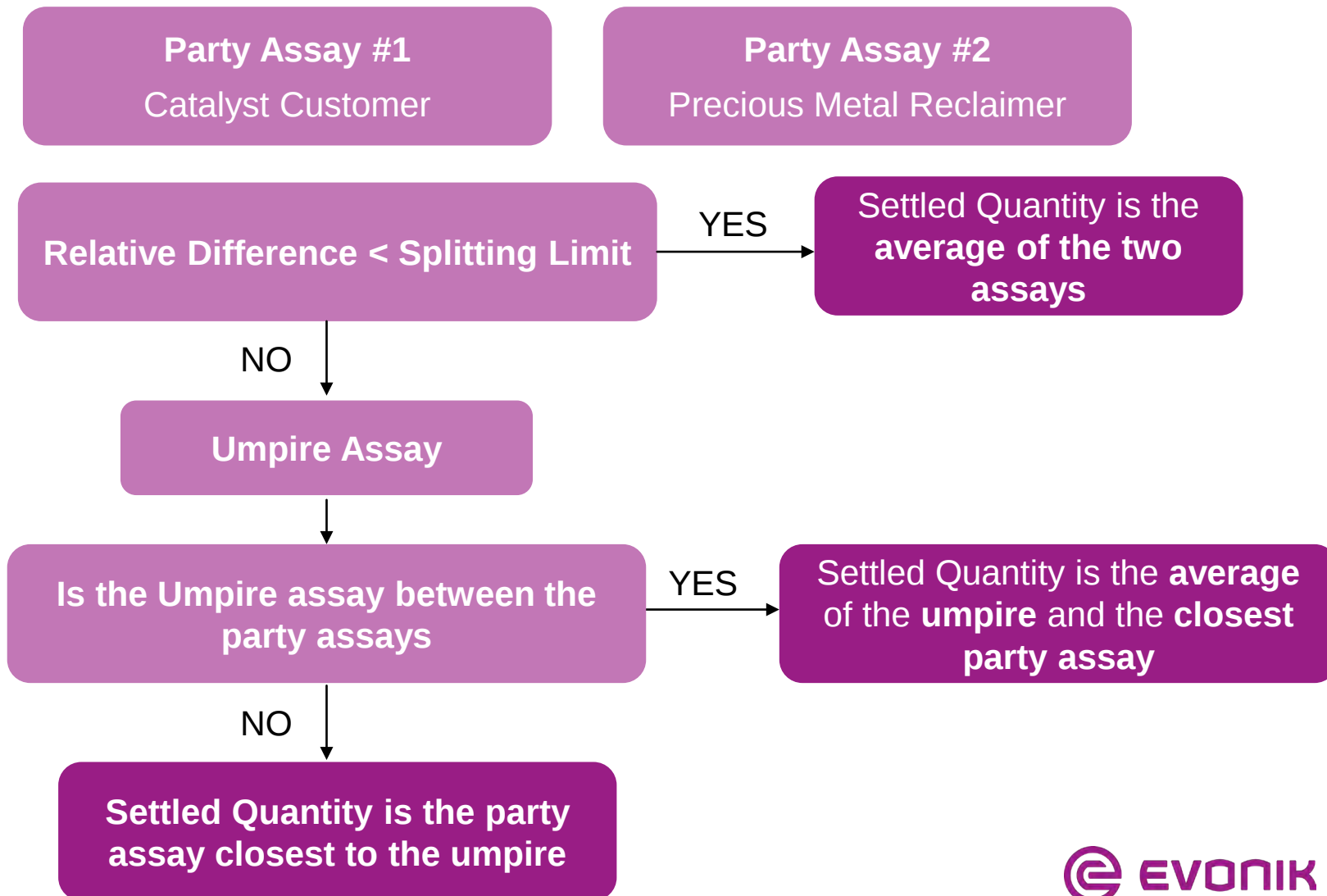
- ☐ Ensure the method for assay is right for your catalyst (validate method)
- ☐ Provide clear and specific instructions for assay, e.g. LOI basis, temperature and time
- ☐ Benchmark and compare labs

Important ! – Make sure LOI conditions are the same for the LOI Weight and the Assay

The Basic Mechanics of a Precious Metal Settlement

Comparing results and settling on an amount

1. Collect samples
2. Prepare samples
3. Analyze
4. Exchange
5. Compare
6. Settlement or Umpire
7. Final Settlement



The Basic Mechanics of a Precious Metal Settlement

Example

Comparing results and settling on an amount

Example:

3 lots

10,000 kgs each (as is)

Target Pd loading 1.00%

Splitting Limit 0.010 or 1.0%

Note – the party's assay farthest from the umpire typically pays the cost of the umpire !

			Relative Difference	Settled Amount or Umpire	Umpire	Settled Assay
Lot 1	Party 1	Party 2				
Lot Weight, kgs (as is)	10000					
Lot LOI (%)	2.10%					
Lot Weight, kgs (LOI basis)	9790					
Pd assay (% , LOI basis)	0.995	1.001	0.006	Settle		0.998
Pd content (kgs)	97.4105	97.9979				97.7042
Pd content (troy ounces)	3131.820	3150.705				3141.262

			Relative Difference	Settled Amount or Umpire	Umpire	Settled Assay
Lot 2	Party 1	Party 2				
Lot Weight, kgs (as is)	10000					
Lot LOI (%)	2.50%					
Lot Weight, kgs (LOI basis)	9750					
Pd assay (% , LOI basis)	0.980	1.018	0.038	Umpire	0.988	0.984
Pd content (kgs)	95.550	99.255				95.94
Pd content (troy ounces)	3072.003	3191.122				3084.542

			Relative Difference	Settled Amount or Umpire	Umpire	Settled Assay
Lot 3	Party 1	Party 2				
Lot Weight, kgs (as is)	10000					
Lot LOI (%)	2.70%					
Lot Weight, kgs (LOI basis)	9730					
Pd assay (% , LOI basis)	0.980	1.018	0.038	Umpire	1.020	1.018
Pd content (kgs)	95.354	99.0514				99.0514
Pd content (troy ounces)	3065.702	3184.576				3184.576

Precious Metal Settlements

Hints to ensure a quality settlement and Best Practices

Always have
someone check
your work

Closely review all
analytical results

Consider the use
of a 3rd party
representative

Validate and
benchmark assay
labs

Review
procedures with
your partner

Be very concise
with language in
procedures

Utilize
spreadsheets to
automatically
calculate results



EVONIK

Leading Beyond Chemistry